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# Reading GPS Time Series Plots Worksheet

The Global Positioning System, GPS, is used to study the Earth, how tectonic plates move and how the Earth's tectonic plates deform. GPS monuments are attached the ground and measure how the earth moves. While the GPS units in a car measure movement in miles per hour, high-precision GPS units used for scientific studies measure how fast or slow the Earth's plate move and can measure **a few millimeters in a year.** Even millimeters can be important because slow moving rock can cause big earthquakes.

**Part 1) Build a gum-drop model of a GPS monument and pinpointing location with GPS.**

**Materials**

- 1 gum drop = GPS Receiver
- 3 small Playdoh feet = Cement
- 4 toothpicks (3 legs, one center post) = Monument braces
- ¼ sheet transparency = 'see-through' crust

**Procedure**:

1. Insert 3 toothpicks diagonally into the gumdrop (the GPS receiver). The toothpicks will act as the legs (braces to hold the monument steady).
2. Insert a slightly shorter toothpick sticking straight down from the middle of the gumdrop. The tip of this toothpick should be just barely above the surface. This will be the *'place marker'*.
3. Put very small pieces of clay on the bottom of the legs (not the place marker). The clay will act as a cement to hold the GPS station in place. In reality the legs of a GPS station are cemented deep into the ground so that if the ground moves, so does the GPS station.

**Pinpointing location with GPS**

1. What do the tops of the stands (not the stand itself) represent?

2. What does the length of string represent?

3. How many satellites are needed to pinpoint the location of a spot on the Earth?

4. Why wouldn't one or two satellites work? Can you draw a diagram to show this?

5. Draw the setup of the demonstration in the space to the right.

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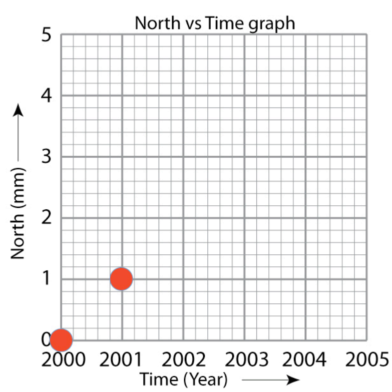
**Part 2) What direction is GPS monument A moving?**
Similar to a car GPS unit, high-precision GPS data is collected as coordinates such as latitude, longitude, and elevation. To make analysis easier to do, scientists convert the data into 4 parts: north, east and vertical elevation, as well as time.

The data in the table show how far GPS Monument A has moved each year. The first column shows the Time in Years. The next two columns show how far the monument moved each year in the North-South, East-West, and the vertical directions. We will make four graphs to study this data.

**GPS Monument A**

| Time (Year) | North (mm) | East (mm) | Height (mm) |
|---|---|---|---|
| 2000 | 0 | 0 | 0 |
| 2001 | 1 | 1 | 0 |
| 2002 | 2 | 2 | 0 |
| 2003 | 3 | 3 | 0 |
| 2004 | 4 | 4 | 0 |
| 2005 | 5 | 5 | 0 |

1. Make a **North vs Time (year) graph** by placing a dot on the graph paper marking each year. On your graph paper, each block represents 1mm.



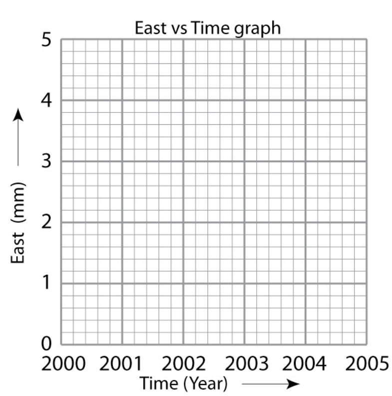

The locations of the monument for the years 2000 and 2001 have been plotted for you.

What direction is GPS Monument A moving? North or South?

What direction would the monument be moving if the North position ***decreased*** from 5 to 0 from year 2000 to 2005?

*Your answer (North or South)?:* ____________________

2. Now make an **East vs Time (year)** graph showing how GPS Monument A moved every year.




What direction is GPS monument A moving? East or West?

What direction would the monument be moving if the East positions ***decreased*** from 5 mm to 0 mm from years 2000 to 2005?

*Your answer (North or South)?:* ______________________

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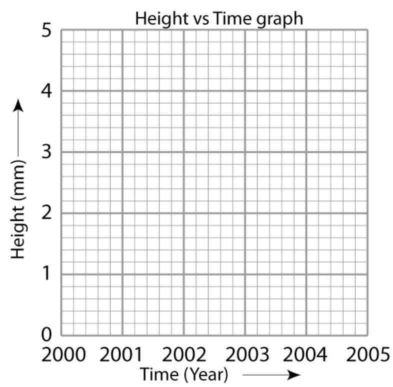
**GPS Monument A**

| Time (Year) | North (mm) | East (mm) | Height (mm) |
|---|---|---|---|
| 2000 | 0 | 0 | 0 |
| 2001 | 1 | 1 | 0 |
| 2002 | 2 | 2 | 0 |
| 2003 | 3 | 3 | 0 |
| 2004 | 4 | 4 | 0 |
| 2005 | 5 | 5 | 0 |

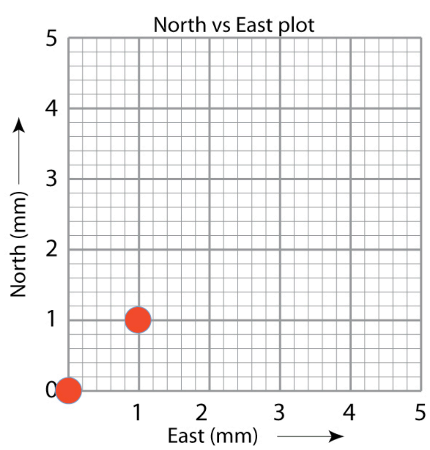
3. And finally make a **Height vs Time (year)** graph showing how GPS Monument A moved every year.




Describe the motion of the monument in the vertical direction. Is GPS Monument A moving in the vertical direction?

*Your answer:* _________________________

4. Now let's plot the North and East positions together on the map grid; North is on the y-axis, East is on the X-axis; the positions from years 2000 and 2001 have been plotted.




- **Plot** the locations of the GPS monument for years 2002 through 2005.
- **Draw** an arrow with the tail at the first point and the arrowhead at the last data point.
- Move your gum-drop GPS monument from its starting position (2000) to the end position (2005).

**According to your map, what direction is your GPS monument moving?**

*Your answer:* _________________________

**Part 3) What direction is GPS monument B moving?**

The data in the table show how far Station B has moved each year. The first column shows the Time in Years.

| GPS Monument B | | |
|---|---|---|
| **Date** | **North (mm)** | **East (mm)** |
| 2000 | 0 | 0 |
| 2001 | -1 | -2 |
| 2002 | -2 | -4 |
| 2003 | -3 | -6 |
| 2004 | -4 | -8 |
| 2005 | -5 | -10 |

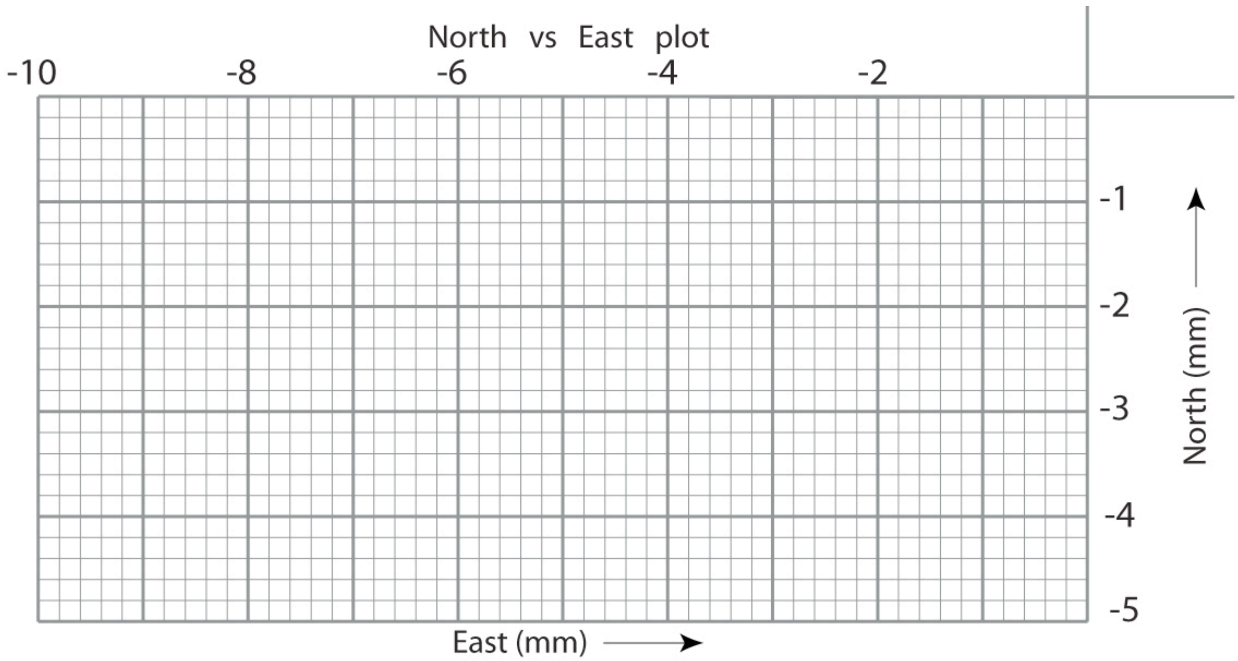
Focus on the data for the **North** data

- Is Monument B moving in a more positive or negative direction?
- What direction is GPS Monument B moving? North or South?

*Your answer:* _______________

Now, focus on the data for the **East** data

- Is Monument B moving in a more positive or negative direction?
- What direction is GPS Monument B moving? East or West?

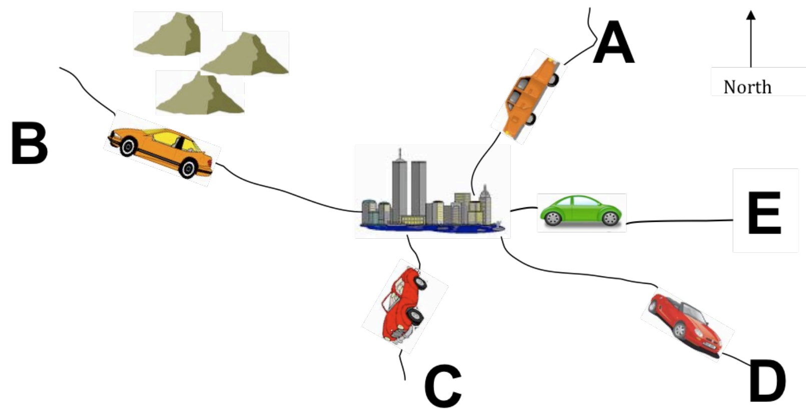



- **Plot** the North and East together on the map grid; the positions from years 1999 and 2000 have been plotted for you. Plot the location for 2001, 2002, 2003, and 2004.
- **Draw** an arrow with the tail at the first point and the arrowhead at the last data point.
- **Move** your gum-drop GPS monument from its starting position (1999) to the end position (2004).

**According to your map, what direction is your GPS monument moving?**

*Your answer:* ______________________________

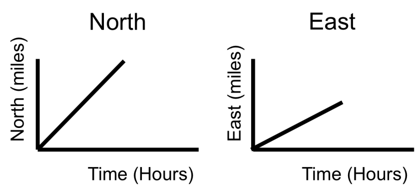
**Part 4: Test your knowledge**



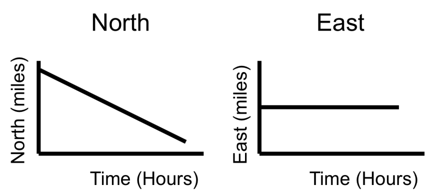

1. Look at the sets of graphed data below and describe what direction each set of graph indicates.
2. Identify the letter of the car (on the map) that matches the direction from step 2.

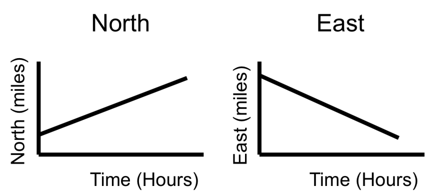
The first example has been done for you. Refer to the previous pages for help.

Direction CAR LETTER



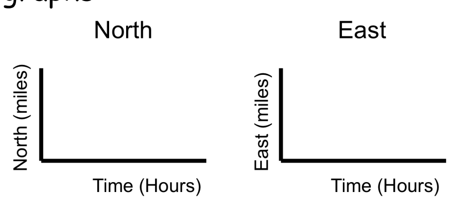

_*north-northeast*_ ____Car *A*____



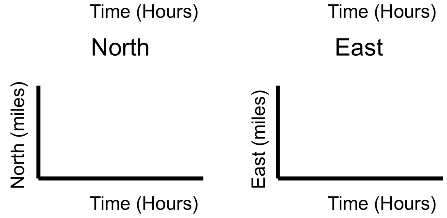

For the two cars remaining, draw the North and East graphs

Which car and what direction?




Car letter ___________

Is moving in direction: __________




Car letter ___________

Is moving in direction: __________

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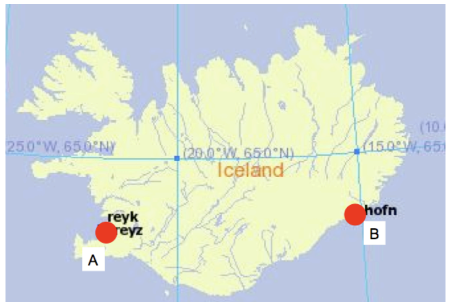
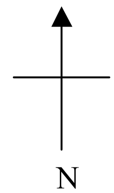
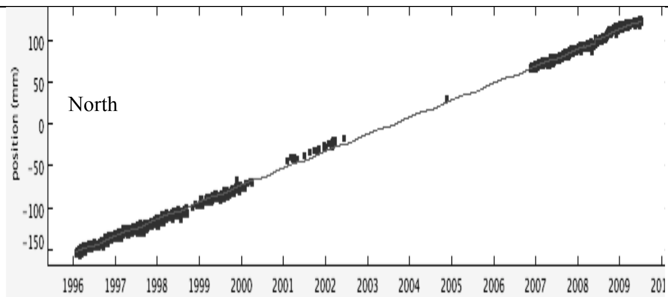
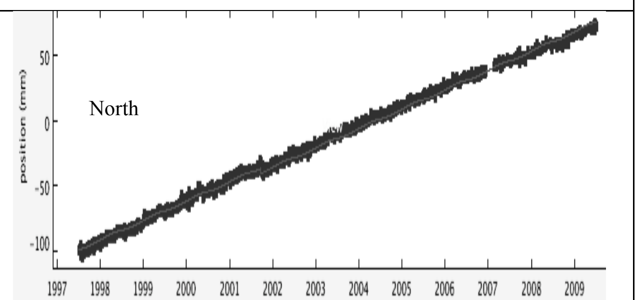
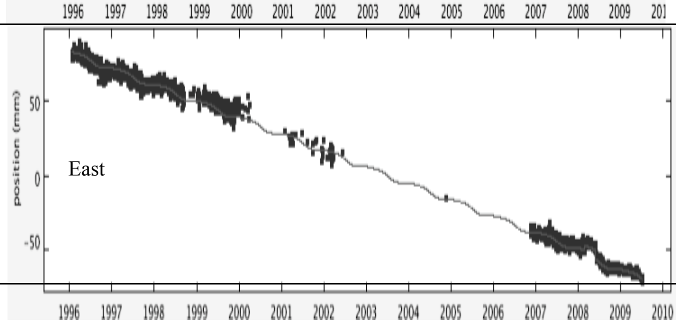
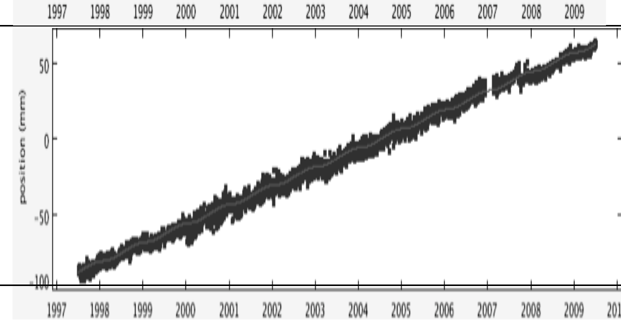
**Part 5: Real GPS Data: Surprising Discoveries**

So far, we've the direction a GPS monument could move, but not how fast a monument is moving. By analyzing multiple GPS Time Series Plots you can determine the directions and rates of regional deformation. Remember, the GPS stations are permanently cemented to the ground, so if the monument is moving … the Earth's plates are moving or deforming. Look at the data from the GPS monuments below, from Iceland.




| GPS Monument REYK | GPS Monument HOFN |
|---|---|
|  |  |
|  |  |
| **a. What direction is Monument REYK moving?**<br><br>______________________________ | **b. What direction is Monument HOFN moving?**<br><br>______________________________ |

c. How did you determine the directions of REYK and HOFN?

d. Are the two monuments moving towards each other, away from each other, or in the same direction?



UNAVCO

Name ____________________ Class ________________ Data ______________

e. Work through the next steps to construct the vectors for these two stations and plot them on the map of Iceland.

| Look at the **1997 to 2007**. In 10 years: | Look at 1998 and 2008. In 10 years: |
|---|---|
| How far north/south did REYK move?<br>_________ to the ________ (North or South) | How far north/south did HOFN move?<br>___________ to the ________ (North or South) |
| How far east/west did REYK move?<br>_________ to the ________ (East or West) | How far east/west did HOFN move?<br>_____________ to the ________ (East or West) |

The distances above are how far each monument moved in 10 YEARS.

The equation for speed is: [                    ]

Now calculate the SPEED of REYK and HOFN in each direction and plot the velocity vectors (the convention is to use a negative number for velocities to the south or west):

| | |
|---|---|
| REYK **North** = ___________ mm/year | HOFN **North** = ___________ mm/year |
| REYK **East** = ___________ mm/ year | HOFN **East** = ___________ mm/year |

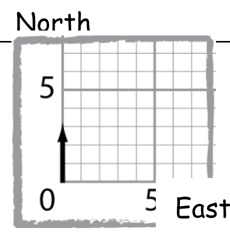
This time we're going to draw two vectors, the north vector and the east vector and then combine them to create a single vector. Each block = 1mm

A vector shows magnitude (the rate of motion) and direction (of motion). Remember:

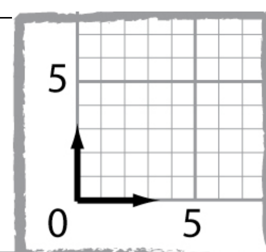
- Tail is the location of the GPS monument
- Length of arrow is the magnitude
- Plotted on a map to show direction

1. **Draw** the first vector arrow along the North axis with the tail at 0. See the diagram to the right for an example
2. **Draw** the east vector arrow along the East axis with the tail at 0.
3. To add the vectors together,
   - *re-draw* the East arrow by **placing the tail of the East vector at the head of the North vector**;
   - then draw a **new vector** from the tail of the North vector to the arrow head of the East vector.

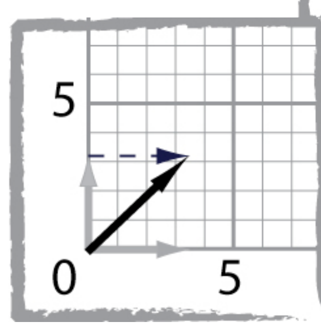
1.




2.




3.



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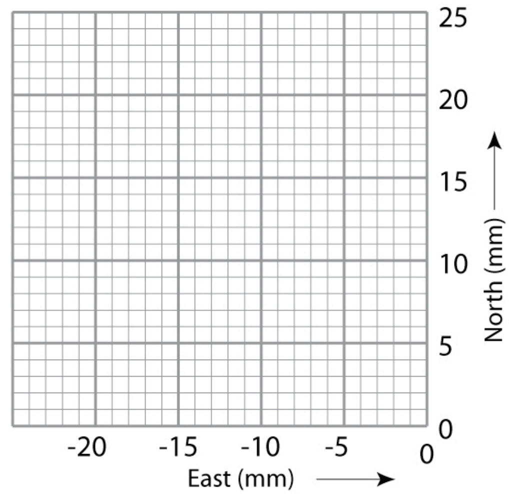
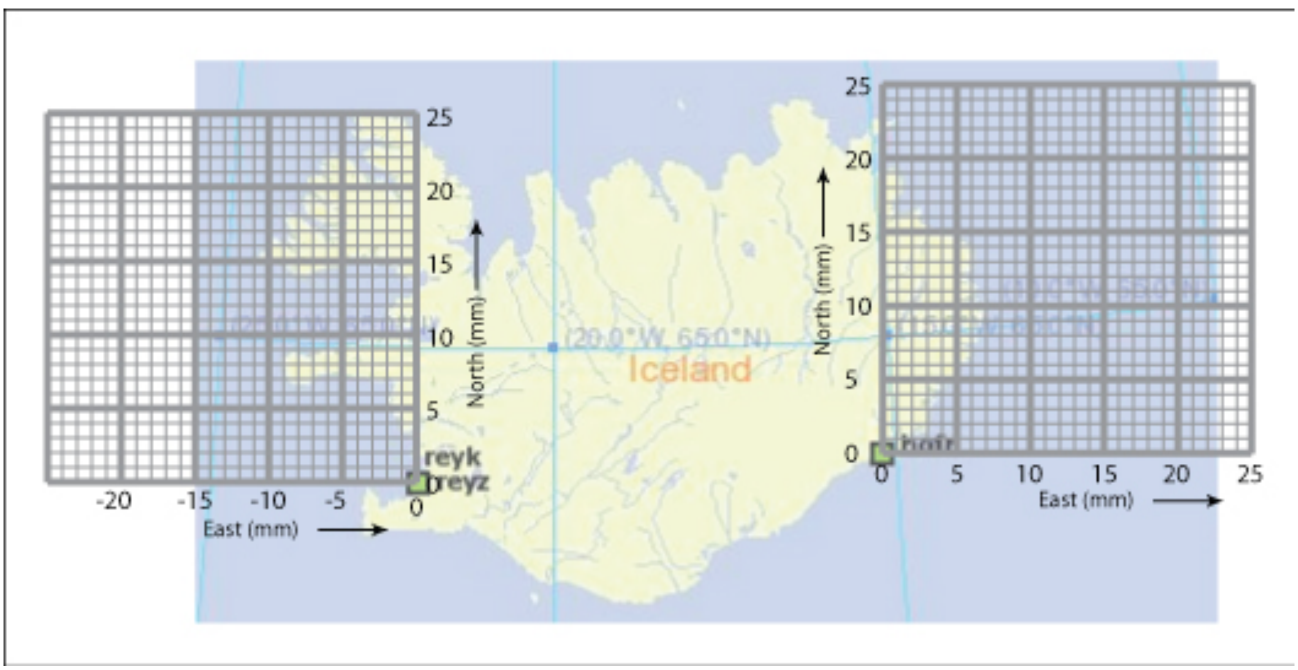
1. **Draw** the first vector arrow along the North axis 20.5 blocks (mm), with the tail at 0.
2. **Draw** the east-west vector arrow along the East axis -11 blocks (mm), with the tail at 0.
3. To add the vectors together,
   - re-draw the East arrow: **Place the tail of the East vector at the head of the North vector**;
   - draw a **new vector** from the tail of the North vector to the arrow head of the East vector.




Now draw your vectors on the map of Iceland:




f. Describe how the vectors are different and how they are the same.

In 500 years, how much further apart will the stations moved?

g. Remember that the monuments are cemented into the ground. If they are moving then the ground must be moving. If you flew in a plane over Iceland, describe the motion of Monuments A and B that you would see. What if you flew over Iceland 100 years later, what would you see?

h. Give one possible explanation for the way the ground is moving in Iceland.

i. Look at the map your teacher provides showing the location of lava eruptions in Iceland. In what way does this support or conflict with your explanation?

j. There are gaps in the data for Monument B. Given what you know about how GPS data are collected, give two possible causes for the gaps.

Bonus:
Calculate the magnitude of the resulting vector:
Two methods:

- Vector magnitude = $\sqrt{[(\text{north magnitude/year})^2 + (\text{east magnitude/year})^2]}$
- Measure the length of the vector _____, measure the width of each block = ________ , resulting vector = [(length of the Vector)/(width of each block)]